

Intraoperative ultrasound to assess for pancreatic duct injuries

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While pancreatic injuries are relatively uncommon, the morbidity and mortality associated with such injuries are high. Of all pancreatic injuries, most result from penetrating rather than blunt trauma.¹⁻⁵ It is estimated that 6% of abdominal gunshot wounds and 2% of abdominal stab wounds result in a pancreatic injury.^{1,6} The mortality associated with pancreatic injuries ranges from 20% to 45%, while the pancreas-specific complication rate is higher than 35%.^{1,3}

Involvement of the pancreatic duct is the main determinant of morbidity and mortality from a pancreatic injury.¹ Not surprisingly, a delay in diagnosis of a main pancreatic ductal injury over 6 hours to 12 hours further contributes to the high complication and death rate of pancreatic injuries.^{7,8} Furthermore, diagnosis of pancreatic ductal involvement requires operative resection rather than placement of drains or nonoperative management.⁹⁻¹¹

However, determining whether the pancreatic duct is involved in the injury remains one of the greatest challenges in trauma surgery. Diagnosing pancreatic ductal injuries often requires a multimodal imaging approach by a multidisciplinary team. Unfortunately, intraoperative cholecystocholangiopancreatography is often nondiagnostic, gastroenterologists may not be available for endoscopic retrograde cholangiopancreatography (ERCP), and the patient may be excluded from magnetic resonance cholangiopancreatography (MRCP) because of skeletal traction equipment or previous metal implants. Surgeon-controlled intraoperative pancreatic ultrasound (US) may overcome these limitations. In this article, we describe our use of intraoperative US as an adjunct to evaluate for ductal involvement in pancreatic injuries.

TECHNIQUE

When a patient is in the operating room undergoing exploration and a pancreatic or duodenal injury is suspected, we perform a full Kocher maneuver to evaluate the duodenum,

uncinate process, head, and body of the pancreas. The lesser sac is also opened along the gastrocolic ligament. If we suspect a distal body or tail injury, we further mobilize the spleen and the tail of the pancreas.

Once the pancreas is fully mobilized, an intraoperative US probe is used along the length of the pancreas. A wide range of US probes may be used. A high-frequency end-fire linear-array transducer may provide the best resolution. A side-fire curved linear-array or a T-shaped side-fire curved linear-array is also acceptable. Generally, a 5-MHz to 10-MHz frequency is selected, with optimal megahertz around 7.5 MHz to 10 MHz. We use the SonoSite MicroMaxx SLT 10-5 MHz 52mm broadband linear array intraoperative US probe (FUJIFILM SonoSite, Inc., Bothell, WA).

The duct is traced from the tail to the head of the pancreas. The confluence of the common bile duct and the pancreatic duct is visualized. This can be performed on the anterior and inferior aspects of the pancreas. Regions of tissue trauma appearing hypodense on US can be assessed for close proximity to the pancreatic duct and raise concern for duct injury. A zone of injury completely enveloping the duct or clear evidence of duct disruption may be discernible. Once identified, the choice of procedure for wide drainage or resection is determined by the surgeon.

DISCUSSION

The diagnosis of pancreatic ductal injuries is paramount after blunt or penetrating trauma. Any delay in diagnosis and treatment is fraught with increased complications and mortality.⁹ Algorithms have been developed to guide surgeons in evaluating the pancreas. The Memphis group has proposed and evaluated a straightforward management algorithm for managing distal pancreatic ductal injuries by using the following categories: duct injury—no (drain only), duct injury—yes (distal pancreatectomy + drain), or duct injury—indeterminate.^{10,11} Those in the indeterminate category are further categorized as either low or high probability for a duct injury based on the assessment of the operating surgeon. While this algorithm has been shown to be safe and is consistent with the Western Trauma Association 2013 algorithm on the management of pancreatic trauma, the categorization of an indeterminate injury as either low or high probability is based exclusively on clinical judgment.⁹ Our proposed technique would be complementary to the intraoperative clinical examination of the pancreas and may allow these indeterminate injuries to be definitively categorized and then managed accordingly.

While computed tomography (CT) scan is often the first modality used, MRCP and ERCP are often required to evaluate the pancreatic duct. However, each of these modalities has significant limitations in their application to pancreatic trauma.

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CT Scan

While the CT scan accurately identifies liver and spleen injuries, its sensitivity and specificity historically for pancreatic injury are approximately 60% to 70%.^{2,4} In a large multicenter American Association for the Surgery of Trauma trial using modern multidetector CT scanners, although the specificity was better than 90%, the sensitivity was still only 47% to 60%.⁷ While the CT scan may be useful as a quick noninvasive screening tool, it often does not rule in or rule out pancreatic duct injury. Figure 1 depicts a CT scan image of a patient who sustained a gunshot wound through the right flank, inferior vena cava, and pancreas. Identification of the pancreatic duct is difficult.

ERCP

This is the most widely used modality in evaluating suspected pancreatic injuries because it can diagnose main duct and side-branch injuries and can also provide preoperative, intraoperative, or postoperative therapeutic options. In one study of 26 patients undergoing ERCP for suspected pancreatic ductal injury, 18 (69%) had substantial pancreatic ductal injuries that were not identified on CT.¹² However, some studies suggest that ERCP may miss up to 25% of pancreatic ductal injuries,¹³ and obtaining a timely ERCP in a traumatized patient is often hampered by logistical, technical, and anatomic considerations.¹² Figure 2 (same patient from Fig. 1) demonstrates a fluoroscopic view of the pancreaticogram obtained during an ERCP.

MRCP

MRCP has recently become more favorable for the trauma patient who may have difficulty getting an ERCP. MRCP has the advantage of being less invasive, quicker, and more readily available than ERCP.² In addition, MRCP may identify other pathology that is not seen on ERCP. MRCP can successfully identify the pancreatic duct through the pancreatic head 97% of the time and through the tail 83% of the time.¹⁴ However, many trauma patients are excluded from MRCP secondary to metal foreign bodies, external fixators, traction pins, or simply by availability.



Figure 1. CT abdomen with intravenous contrast demonstrating a penetrating injury to the head of the pancreas (arrow).

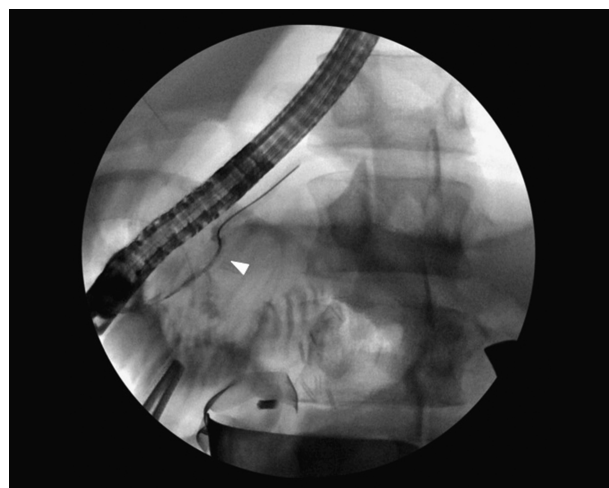


Figure 2. Intraoperative pancreatogram confirmed that the main pancreatic duct (arrowhead) was not injured.

Cholecystocholangiopancreatography

One intervention often cited as a means to diagnose a pancreatic ductal injury is the use of cholecystocholangiopancreatography. For these studies, we prefer to use methylene-blue dye mixed with radiopaque dye injected through the gallbladder. While in our experience this works well for the biliary system, the pancreatic duct often does not opacify. Even after the administration of narcotics to stimulate closure of the sphincter of Oddi, the pancreatic duct may not be visible on fluoroscopy imaging and no blue dye may be present in the field of view.

Intraoperative US

The use of US has increased greatly during the recent years to nearly all aspects of medicine. The general and trauma surgeons have become more facile with the application of US in a wide



Figure 3. Intraoperative US of the pancreatic head, which shows normal pancreatic tissue between the injury (arrow) and the main pancreatic duct (arrowhead).

TABLE 1. Questions Concerning Pancreatic Imaging

	ERCP	MRCP	Cholecystocholangiopancreatography	Intraoperative US
Availability	Is gastroenterology available? Is the fluoroscopic and endoscopic equipment available?	Is MRCP available? Is a radiologist experienced in MRCP evaluation available for interpretation?	Is fluoroscopy available in the operating room? Is blue dye available in the operating room?	Is a US machine available? Is a sterile probe or sterile probe cover available?
Exclusions/limitations	Will the gastroenterologist perform it supine? Can the patient be prone? Is the abdomen closed/temporarily closed? Is there a duodenal injury? Do they have anatomy precluding ERCP? Previous gastric bypass? Duodenal diverticulum?	Does the patient have any metal (external fixator, traction pins, previous hardware, metallic foreign body)? Can magnetic resonance imaging support the current ventilator requirements?	Is the anatomy favorable to perform a cholecystopancreatogram? Are surgical instruments precluding a good view of the pancreatic duct?	Can the operator identify the pancreatic duct by US?

variety of circumstances, so its application to pancreatic ductal trauma should not be overlooked. An abundance of literature has demonstrated the capability to identify lesions, vessels, lymph nodes, and tumor burden within the pancreatic ductal systems using US.^{15–17} Currently, there are no studies comparing the sensitivity and specificity of US for pancreatic ductal injuries to those of ERCP, MRCP, and cholecystocholangiopancreatography. However, the technique can be quickly learned and readily applied as an adjunct that can be added to the trauma surgeon's armamentarium. Future studies are needed to systematically determine the utility of this technique in diagnosing pancreatic ductal injuries.

Intraoperative US should be considered whenever the trauma surgeon is already in the operating room with an open abdomen at either the index operation of a subsequent exploration and a pancreatic duct injury is suspected. For proximal injuries, our preference is for wide drainage if the pancreatic parenchyma and duodenum are otherwise preserved. If there is marked injury to the pancreatic head with ductal involvement, we generally proceed with staged pancreaticoduodenectomy.¹⁸ For distal injuries with ductal involvement, we perform a distal pancreatectomy with or without splenic preservation, depending on the patient's condition.

Figure 3 is an intraoperative US obtained (in the same patient from Figs. 1 and 2), demonstrating no apparent injury to the pancreatic duct and no proximity of the hypodense region of injury to the duct. In addition, strong consideration should be given to the questions in Table 1, when evaluating the modalities available to exclude a pancreatic duct injury. While there are no studies comparing the specificity and sensitivity of US to those of ERCP, MRCP, and cholecystocholangiopancreatography, the technique can be quickly learned and readily applied. Future studies are needed to systematically determine the utility of this technique in diagnosing pancreatic ductal injuries.

CONCLUSION

Diagnosing a pancreatic duct injury remains a significant challenge in the management of pancreatic trauma. For trauma patients already in the operating room for concomitant injuries,

intraoperative US may provide an accurate diagnosis expeditiously. For trauma patients who are not eligible for MRCP or for those with difficult anatomy where ERCP cannot be completed or where ERCP is not available, pancreatic US is readily available. We recommend the use of intraoperative US to assist with the immediate diagnosis of a pancreatic ductal injury.

AUTHORSHIP

L.J.H. contributed in the literature search, study design, data interpretation, writing, and figures. P.A.L. contributed in the literature search, study design, data interpretation, writing, and figures. J.W.C. contributed in the literature search, study design, data interpretation, writing, and figures.

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DISCLOSURE

The authors declare no conflicts of interest.

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